Population size and trends of seabirds breeding on Gull and Great Islands, Witless Bay Islands Ecological Reserve, Newfoundland, up to 2003

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POPULATION SIZE AND TRENDS OF SEABIRDS BREEDING ON GULL AND GREAT ISLANDS, WITLESS BAY ISLANDS ECOLOGICAL RESERVE, NEWFOUNDLAND UP TO 2003

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Summary

The Witless Bay Islands Ecological Reserve, in south-eastern Newfoundland, supports large and diverse populations of breeding seabirds, including internationally important numbers of Atlantic Puffins (*Fratercula arctica*), Common Murres (*Uria aalge*) and Leach's Storm-Petrels (*Oceanodroma leucorhoa*). During the summers of 1999 to 2003, breeding populations of five seabird species, namely Common Murres, Razorbills (*Alca torda*), Atlantic Puffins, Black-legged Kittiwakes (*Rissa tridactyla*) and Northern Fulmars (*Fulmarus glacialis*), were surveyed on Gull and Great Island in the reserve. Common Murres were surveyed by counting adults on breeding areas from boats, and an estimate of the number of breeding pairs was derived using a correction factor obtained from a detailed study plot on Great Island. Populations have increased substantially on both islands, with an estimated 1 632 ± 197 (± 1 SE) and 7 369 ± 889 pairs breeding on Gull and Great Island, respectively in 2003. Razorbills were counted from ground surveys of adults in nesting areas. Razorbill populations remain low, but have certainly increased in recent decades, with an estimated 285 and 221 pairs breeding on Gull and Great Island, respectively, in 2003. The Atlantic Puffin breeding population was estimated on Gull Island in 2003, using total area occupied and burrow occupancy calculated from 4 different areas across the island. Additionally, data from 100 randomly-placed burrow occupancy plots were available for 1984 and 1985, and provided estimates for these years (based on using a total area occupied measured in 1979). In 2003, an estimated 140 429 ± 5 088 (95% CI: 130 137 – 150 721) pairs of Atlantic Puffins bred on Gull Island, surpassing Great Island as the largest known colony in North America. Black-legged Kittiwakes were surveyed by counts from boats of active nests. In contrast to the auks, Black-legged Kittiwake populations have declined in recent years, with only 4 314 and 9 292 pairs remaining to breed on Gull and Great Island, respectively, in 2003. Northern Fulmars were censused somewhat haphazardly with a variety of methods (boat and ground counts). In 2003, a minimum of 6 and 34 site-holding pairs were present on Gull and Great Island, respectively, suggesting the population has not changed greatly in recent years. The first documented nesting of Northern Ravens (*Corvus corax*) occurred on Great Island in 2000 and Gull Island in 2002.

Overall, populations of auks breeding on Gull and Great Island are showing increases in recent years, and appear to be healthy. Black-legged Kittiwakes, on the other hand, have been declining since the 1990s. Auk populations are increasing and kittiwakes are declining at most colonies monitored in eastern North America. Given that seabird populations in Witless Bay are matching these regional trends, there do not appear to be any pressing site-specific conservation issues in the Reserve. Continued monitoring, with a special focus on kittiwakes, is probably warranted for the future.

Résumé

La Réserve Écologique des Îles de Witless Bay, située au sud-est de Terre-Neuve, héberge des populations importantes et diversifiées d'oiseaux marins nicheurs, incluant des concentrations d'importance internationale de macareux moines (*Fratercula arctica*), de guillemots marmettes (*Uria aalge*), ainsi que d'océanites cul-blanc (*Oceanodroma leucorhoa*). Au cours des étés de 1999 à 2003, on a recensé cinq espèces d'oiseaux marins, c'est-à-dire le guillemot marmette, le petit pingouin (*Alca torda*), le macareux moine, la mouette tridactyle (*Rissa tridactyla*), et le fulmar boréal (*Fulmarus glacialis*), en nidification dans la réserve sur les îles Gull et Great. On a compté en bateau les guillemots marmettes dans les zones de nidification et on a évalué le nombre de couples au moyen d'un facteur de correction obtenu grâce aux parcelles d'une étude détaillée sur l'île Great. Les populations ont connu une forte augmentation dans les deux îles, avec un nombre de couples reproducteurs évalué à 1 632 ± 197 (± 1 SE) sur l'île Gull et 7 369 ± 889 sur l'île Great, en 2003. On a recensé au sol les petits pingouins en comptant les adultes dans les zones de nidification. Les populations de petits pingouins demeurent petites mais ont certainement subit une augmentation au cours des dernières décennies, l'estimation du nombre de couples étant de 285 sur l'île Gull et 221 sur l'île Great, en 2003. On a produit une estimation de la population nicheuse de macareux moines sur l'île Gull en 2003, en utilisant le secteur total occupé et le taux d'occupation des terriers calculés de 4 régions différentes de l'île. De plus, des données de 100 parcelles situées au hasard évaluant les taux d'occupation des terriers étaient disponibles pour les années 1984 et 1985, et ont fourni une estimation pour ces années (basée sur le secteur total occupé obtenu en 1979). En 2003, le nombre de couples de macareux moine en nidification sur l'île Gull était évalué à 140 472 ± 5 088 (intervalle de confiance [IC] de 95%: 130 137 – 150 721), surpassant l'île Great comme la plus grande colonie connue en Amérique du Nord. On a recensé les mouettes tridactyles à partir de dénombrements en bateau des nids actifs. En comparaison des Alcidés, les populations de la mouette tridactyle ont décliné dans les dernières années, avec seulement 4 314 et 9 292 couples reproducteurs sur les îles Gull et Great, respectivement, en 2003. Les recensements du fulmar boréal ont été effectués de manière moins systématique, soit avec un assortiment de méthodes (en bateau et au sol). En 2003, il y avait au moins 6 couples qui occupaient un site sur l'île Gull et 34 couples territoriaux sur l'île Great, ce qui suggère que la population a peu changé récemment. On note la première observation de corbeaux (*Corvus corax*) en nidification sur l'île Great en 2000 et sur l'île Gull en 2002.

En général, les populations nicheuses d'Alcidés sur les îles Gull et Great montrent des augmentations récentes et paraissent en santé. En revanche, les populations de la mouette tridactyle ont décliné depuis les années 1990. À travers la région de l'est de l'Amérique du Nord, les populations d'Alcidés augmentent tandis que les populations de la mouette tridactyle sont en déclin dans la plupart des colonies où des inventaires sont effectués. Puisque les populations d'oiseaux marins à Witless Bay suivent les mêmes tendances que celles observées dans la région, il ne semble pas avoir de problématiques de conservation pressantes dans la réserve. Le suivi des populations d'oiseaux marins nicheurs, et en particulier de la mouette tridactyle, devrait être maintenu dans le futur.

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1. Introduction

1.1 Witless Bay Islands Ecological Reserve and protection

From April through September, millions of seabirds from 10 different species come to breed in the Witless Bay Islands Ecological Reserve. The Reserve consists of a group of four islands (Gull, Green, Great, and Pee Pee Islands) approximately 4 km offshore of southeast insular Newfoundland (Figure 1) and 30 km south of St. John's, the capital of Newfoundland and Labrador. Gull, Green, and Great Islands are among the most important seabird breeding sites in eastern North America. Great Island alone supports the largest Atlantic Puffin (*Fratercula arctica*) colony in the Northwest Atlantic (Rodway et al. 2003) while Green Island is densely populated with Common Murres (*Uria aalge*). Green Island is also the breeding ground for a small group of Thick-billed Murres (*U. lomvia*), making it one of the most southerly colonies of the species' breeding range. In addition, Leach's Storm-Petrels (*Oceanodroma leucorhoa*) and Black-legged Kittiwakes (*Rissa tridactyla*), two other major species breeding in the Reserve, are found in large numbers on Gull, Green and Great Islands.

Gull, Green and Great Islands were first protected in 1964 collectively as a Wildlife Reserve under the *Wildlife Act*. In 1983, these islands were protected under the *Wilderness and Ecological Reserves Act (1980)* as an Ecological Reserve. At that time, the boundaries were defined as the three islands and the adjoining waters under provincial jurisdiction. Following the approval of the Witless Bay Islands Ecological Reserve Management Plan in 1994, the marine boundaries for commercial traffic were limited to one kilometre around the three major islands and included Pee Pee Island because of its importance to Atlantic Puffins. This is the boundary currently in place. Under the current legislation, access on these islands is only allowed under permit.

Following the groundfish moratorium in 1992, ecotourism in Witless Bay has increased dramatically with several tour boat operators taking advantage of the opportunities to view the large numbers of seabirds, as well as other popular attractions such as whales and icebergs. Although recreational boaters and kayakers must maintain certain distances from the islands (see Witless Bay Ecological Reserve Management Plan 1994), tour boat operators are currently exempted from these operating distances.

1.2 History of research

Over the past few decades, the islands in the Reserve have regularly been the summer homes for investigators, and their students, interested in the population and breeding biology of various seabirds. The following is a summary of some of the major research programs that have existed over the years, along with some of the studies which resulted from these programs. This is by no means a comprehensive summary, but merely highlights some major contributions related to seabird research.

Initial attempts at estimating population sizes of seabirds breeding in the Witless Bay Islands Ecological Reserve can be dated back to the 1940s, with H. Peters and T. Burleigh estimating numbers on Green and Gull Island (Peters and Burleigh 1951). L. Tuck visited Green, Gull, and Great Island throughout the 1950s. These historical accounts have provided some insight on colonization dates and expansion of various species. For example, Common Murres began breeding on Green Island around 1936 (Tuck 1961) and on Gull Island in 1962 (as referenced in Mahoney 1980). No Common

Murres were reported breeding on Great Island in 1950 (see Cairns and Verspoor 1980) but were regular breeders by 1968 (Nettleship 1972ab). In general, it appears that Green Island was the primary colony for most major breeding seabirds, such as Common Murres, Black-legged Kittiwakes, and Atlantic Puffins, with the other two islands accommodating the expanding populations. Changes in seabird populations since the 1940s have been summarized up to 1979 in Cairns and Verspoor (1980).

Until 1959, visits to the islands in the Reserve were limited to activities related to the census of breeding seabirds. In 1966, W. Threlfall of Memorial University of Newfoundland began a research program on Gull Island which lasted until 1984. Avian studies resulting from this program focused on the diet of Herring Gulls (Threlfall 1968a), the breeding biology of Black-legged Kittiwakes (Maunder and Threlfall 1972), the climate, vegetation, and avian populations of the island (Haycock 1973), ectoparasites of auks (Eveleigh 1974) and gulls (Threlfall 1968bc), and the breeding biology of Common Murres (Mahoney 1980, Mahoney and Threlfall 1981) and Great Black-backed Gulls (*Larus marinus*; Roy 1986). Breeding population sizes of most major seabird colonies were also assessed from 1969-1971 (Maunder and Threlfall 1972, Haycock 1973). The current cabin on Gull Island was built in 1974 by Parks and Natural Areas Division under the Summer Naturalist Program. This program was designed to bring tourists onto Gull Island and educate them on the natural history of the island. Because of disturbance issues, however, the program was quickly discontinued.

Research on Great Island intensified in 1967 with D. Nettleship from McGill University, in collaboration with CWS (Canadian Wildlife Service), residing on the island to assess factors contributing to the breeding success of Atlantic Puffins (Nettleship 1972ab). D. Nettleship built a cabin on the southwest part of the island as well as two wooden observations blinds. The cabin and one of the wooden blinds still stand today. The collection of puffin and storm-petrel eggs was also initiated in 1968, by P. Pearce and D. Nettleship of CWS, as part of a long-term program monitoring contaminant levels in the marine environment in Eastern Canada (Pearce et al. 1979, Noble and Elliott 1986, Pearce et al. 1989, Noble and Burns 1990, Elliott et al. 1992). Eggs were collected every four years on Great Island from 1968-1988, with egg collection continuing on Gull Island from 1992 to present, also at four-year intervals (N. Burgess, pers. comm.).

In 1973, R. Montgomerie, under the CWS program "Studies on northern seabirds" (initiated by D. Nettleship), conducted the first major census of seabirds on all four islands in the Reserve. These population estimates have been presented in several reports, including Brown et al. (1975), Cairns and Verspoor (1980), and Nettleship (1980). In 1979, D. Cairns and E. Verspoor revisited Gull, Green, Great, and Pee Pee Island to obtain new population counts for the major seabird species and to provide estimates for species that had not been censused since the early 1970s (Cairns and Verspoor 1980, Nettleship 1980).

From 1976-1978, research on Great Island was resumed by R. Pierotti from Dalhousie University, in collaboration with CWS (D. Nettleship). This study focused on various aspects of Herring Gull (*Larus argentatus*) breeding biology, including habitat selection and reproductive success (Pierotti 1982), interactions with puffins (Pierotti 1983), and diet preference (Pierotti and Annett 1991). Meanwhile on Gull Island, gull and puffin interactions were being studied by J. Rice in 1978 and 1979 (Rice 1985, 1987), while J. Lien (Memorial University of Newfoundland) had a student investigating habitat selection in Leach's Storm-Petrels (Grimmer 1980).

In 1982, W. Montevecchi (Memorial University of Newfoundland) re-initiated a research program in the Reserve, which lasted until 1986. A permanent wooden blind overlooking a Common Murre plot on the south-east part of Great Island was built in 1985 by D. Cairns. Studies stemming from this program focused on activity budgets and energetics of Common Murres (Cairns et al. 1987, Cairns et al. 1990) and Leach's Storm-Petrels (collected from Green Island; Montevecchi et al. 1992), and interactions of Common Murres and Atlantic Puffins with their main prey, capelin (*Mallotus villosus*; Piatt 1987, Piatt 1990, Burger and Piatt 1990). During this time, investigations from the CWS research program "Studies on northern seabirds" (D. Nettleship) shifted toward the incidental by-catch of seabirds in fishing nets in the Witless Bay Reserve (Piatt et al. 1984, Piatt and Nettleship, 1985, 1987), however population surveys for burrow nesting species were conducted in 1984 and 1985. In 1985 and 1986, A.E. Storey (Memorial University of Newfoundland) also had a student on Gull Island investigating sex differences in reproductive behaviour of puffins (Creelman 1987, Creelman and Storey 1991).

In 1988, J. Porter (Department of Fisheries and Oceans; DFO) initiated the investigation of puffin and kittiwake reproductive success on Gull Island (Chatman 1989). Black-legged Kittiwakes became a species of concern in the 1990s, following the documentation of low breeding success in 1991 on Gull Island and in other colonies in the Northwest Atlantic (Neuman 1993; under J. Porter (DFO) and J. Chardine (CWS)). In 1992 and 1993, under the supervision of W. Montevecchi, H. Regehr investigated the relationship between capelin availability and the breeding success of kittiwakes on Great Island (Regehr 1994, Regehr and Montevecchi 1997), which yielded additional studies related to the breeding success of other seabirds (Regehr and Rodway 1999, Rodway and Regehr 1999). During this time, under the supervision of W. Montevecchi and J. Chardine (CWS), M. Rodway investigated various aspects on the breeding performance of Atlantic Puffins (Rodway 1994, Rodway 1997, Rodway and Montevecchi 1996, Rodway et al. 1998) also on Great Island. In 1993 and 1994, a census was conducted on Atlantic Puffins to estimate the number of breeding pairs on Great Island (Rodway et al. 2003).

Research on Great Island was continued in 1995 by A.E. Storey (Memorial University of Newfoundland) with a research program primarily focusing on the long-term monitoring of individual Common Murres. Various aspects of breeding biology of Common Murres have been studied, including extra-pair copulation and paternity (Walsh 2001), divorce rates and contributing factors (Moody 2001, Moody et al. in press), parental allocation toward male and female chicks (Cameron 2003), and sex differences in behavioural and physiological responses of breeding adults (Wilhelm and Storey 2002, 2004, Wilhelm 2004). These studies were conducted on the same murre plot and in the same blind as D. Cairns during the 1980s. The blind was functional until the 2001 breeding season, but was replaced at the beginning of the 2002 breeding season by P. Taylor and G. Robertson (CWS).

In 1996, W. Montevecchi also re-initiated a research program on Great Island, which initially focused on habitat utilization of Leach's Storm-Petrels (Stenhouse 1998, Stenhouse and Montevecchi 2000) and their interaction with gulls (Stenhouse and Montevecchi 1999a, Stenhouse et al. 2000). In 1996 and 1997, population estimates of Northern Fulmars (*Fulmarus glacialis*) were conducted on Great and Ship Island (see Figure 1) by I. Stenhouse and K. Squires. These census results along with other fulmar

surveys in Witless Bay and in Eastern Canada are summarized in Stenhouse and Montevecchi (1999b). In 1998, W. Montevecchi expanded his program on Great Island to include foraging strategies of Common Murres (Davoren 2001, Davoren and Montevecchi 2003, Davoren et al. 2003) and in collaboration with D. Ballam (Province of Newfoundland and Labrador), effects of tour boats on the behaviour of auks (Logan et al. 2001).

Meanwhile, research on Gull Island was resumed in 1990 by J. Chardine (CWS) and later with I. Jones (Memorial University of Newfoundland), under the Atlantic Cooperative Wildlife Ecology Research Network (ACWERN). Studies include the effects of tour boats on alcids (Hearne 1998) and the effects of predation by gulls on kittiwakes (Massaro 2000, Massaro et al. 2000). I. Jones had an additional student in 1997 and 1998 studying diet, growth, and success of Atlantic Puffin chicks (Baillie 2001, Bailllie and Jones 2003, 2004). G. Robertson (CWS) succeeded J. Chardine as the CWS Seabird Scientist in Newfoundland, and expanded the program to monitor vital rates of important species in Witless Bay. This included developing or expanding banding programs of puffins (started in 1997), kittiwakes (early 1990s), Herring Gulls (1999), Great Black-backed Gulls (2000), Common Murres (2001), and monitoring productivity of selected species. Further collaboration with ACWERN led to theses on the impact of large gull predation on seabird populations on Gull island (Veitch 2003) and the utility of attendance counts and other measures to assess population trends of puffins (Calvert and Robertson 2002ab). A. Hedd and W. Montevecchi established long-term monitoring plots for Leach's Storm-Petrels on Gull Island in 2003. Studies are currently underway on Gull Island to assess the impact of tour boat disturbance on puffins by using stress hormones (C. Baker, supervised by A. Storey, D. McKay and G. Robertson), determine winter movement of puffins by data loggers (D. Fifield, supervised by W. Montevecchi and G. Robertson) and parasitology of seabirds (S. Muzzafar, supervised by I. Jones).

1.3 Objectives

Although much research has been focused on the seabirds in Witless Bay, less attention has been given to monitoring population numbers in recent decades. To determine population status and trends of seabirds breeding in Witess Bay, CWS re-initiated a monitoring program to census major breeding species on Gull (starting in 1999) and Great Island (2001). This report focuses on population counts of breeding Atlantic Puffins, Common Murres, Razorbills and Black-legged Kittiwakes. It also presents recent data on Northern Fulmar, updating the previous comprehensive summary provided by Stenhouse and Montevecchi (1999b). Results for Herring Gulls and Great Black-backed Gulls and Leach's Storm-Petrels have been reported previously, so are not repeated in this report (Robertson et al. 2001, 2002a).

2. Study site

2.1 Gull Island (47°15'N, 52°46'W)

The topography, vegetation, and avifauna of Gull Island, the largest of the group (1.6 km x 0.8 km), have been described in detail in Haycock (1973). Briefly, Gull Island is mainly forested with edges consisting of either exposed grassy hummock or rocky slopes and vertical cliffs, with numerous narrow ledges. Deep coves on the north-eastern end are bordered by steep cliffs with maximum relief amounting to 69 meters. The southern end, slightly lower in elevation, is characterized by three coves and a rocky

projection on the southwest corner, referred to as the Finger. The Saddle, a low lying rocky area, splits the Finger roughly in half along its east-west axis.

2.2 Great Island (47°11'N, 52°46'W)

Great Island, a slightly smaller island (1.4 km x 0.7 km), is less forested and characteristically more rugged. The island's upper periphery consists of grasses, exposed peat, and small flowering plants. This vegetation edge then gives way to steeper rocky slopes and vertical cliffs surrounding numerous deep coves. Peak elevation is approximately 83 meters, occurring on one of Great Island's three, high north-south ridges. A more detailed description on the island's topography and vegetation can be found in Nettleship (1972b).

3. Methods

3.1 Methods common to more than one species

To assess number of breeding Black-legged Kittiwakes, Common Murres and Northern Fulmar, we counted birds or nests (see below for species-specific details) on all nesting cliffs by circling the whole island in inflatable zodiacs outfitted with outboard motors. Razorbills were counted during these boat surveys, but were also counted from the ground (see 3.3). During boat surveys, 3-4 workers were present, one driving the boat, one recording the data on maps of the island and the remainder counting birds or nests. Four observers proved to be valuable, as one could concentrate on kittiwake nests, while the other would count Common Murres and Razorbills. In each case counts were called out by observers and recorded on the maps. Boat surveys were conducted on 15 June 2001, 4 July 2002 and 2 July 2003 on Gull Island, and on 4 July 2002 and 30 June and 2 July 2003 on Great Island (the survey had to be abandoned half way through on 30 June 2003 on Great Island, due to freshening winds). Surveys generally took 2-3 hours to complete, and were conducted during reasonable boating and observation conditions (< 1 m swells and no precipitation).

3.2 Common Murres

Breeding Common Murre numbers were estimated by counting all birds present at a nesting location from the boat survey. In locations where birds were clustered together at high densities, i.e. 200+ individuals, numbers were estimated. For colonies up to about 500 pairs, groups of 10 birds were generally counted, while for larger colonies (> 500 pairs), birds were counted as clumps of 50 or 100 birds. When breeding areas could not be counted from the boat, locations were counted from land; these counts were usually conducted within a week of the boat survey.

To estimate a k-ratio, a value which translates the number of adults to the number of breeding pairs, we used data collected at the Cairns blind in 2002 and 2003 (southeast portion of Great Island). Long-term studies of Common Murres have been conducted at this blind by Anne Storey and her research associates. This plot is monitored regularly, and the number and location of all eggs laid on the plot are known. On, or close to the day of the boat survey, a count of all adults on the plot was also conducted, which provides the data needed for a k-ratio (number of eggs/number of attending adults). Boat counts were multiplied by the k-ratio to obtain the number of

breeding pairs (Birkhead and Nettleship 1980). For the count on Gull Island in 2001, a mean of the 2002 and 2003 k-ratios was used.

3.3 Razorbills

To assess the number of Razorbills present on Gull and Great and Islands, researchers surveyed areas from the ground as well as from boats. For ground counts, the periphery of the entire island was walked to look for adult Razorbills. Where they were found, the nesting area was approached to within 50-100 m, depending on the site, so that nesting birds would flush from crevices, but hopefully not flush from the general nesting area. On Great Island, adult Razorbills were counted immediately upon having approached the nesting area. On Gull Island, adult Razorbills were counted repeatedly for 5-10 minutes, to obtain a maximum number present. It was soon discovered that some of the birds that flushed would soon return to nesting area if observers were not too close, or could be seen on the water at the base on the nesting area. Once the count was relatively stable, observers moved on to search for the next site. Eggs were counted in some areas sporadically, mostly in 1999 and 2003 to try and assess k-ratios of Razorbills nesting on Gull Island. Overall, it was determined that the topography made it difficult to be sure that all eggs in a plot were counted, and in many areas, nesting areas could not be safely reached. One plot that was accessible was at the northwest corner of the Saddle and eggs were counted in this plot in 1999 and 2003. During the boat survey of cliff nesting birds on Gull and Great Island, number of adults present in nesting areas was counted. No repeat counts were conducted in these cases.

3.4 Atlantic Puffins

3.4.1 2003

Atlantic Puffin breeding populations were assessed by calculating occupied burrow densities and total area of occupied habitat used by breeding puffins. A burrow was defined as a suitable tunnel that could house a pair of breeding puffins, and did not include unsuitably short holes, or additional entrances to a burrow. A hole was defined as any suitable entrance that could lead to a puffin burrow, when assessed by an observer standing up (i.e. not kneeling down to look in the hole). Holes may, or may not, lead to burrows, whereas a burrow always begins with a hole.

Recent studies that have calculated Atlantic Puffin breeding population sizes in Newfoundland and Labrador have used island-wide total hole counts instead of using estimates of occupied area (Robertson and Elliot 2002ab, Robertson et al. 2002b). Using total hole counts, rather than estimating densities of occupied burrows and extrapolating to the area of the colony, can remove biases associated with uneven burrow densities across the breeding colony. However, total hole counts were simply not feasible on Gull Island, as the nesting area was far too extensive to accurately count all the holes. Therefore, we mapped the distribution of occupied habitat on a large scale map (1:2690) of Gull Island. A UTM grid was overlaid on the map, and 20 meter contours were also included to increase the precision of the sketch of the occupied area on the map. The area of occupied habitat on Gull Island occurs in a regular continuous band around the island, and we feel that our mapping effort accurately encompassed the area occupied by puffins.

Hole and burrow occupancy rates were assessed by grubbing (reaching into the hole as far as possible, using a 30-40 cm stick or spoon to extend reach if necessary) all holes in randomly placed plots. As burrow densities are known to vary across habitats, even within an island (Nettleship 1972ab), we stratified Gull Island into four, roughly equal, sections, based on known differences in the habitat between the north, east, west and south sides of the island (Robertson et al. 2001). Within each of the strata, 8 to 12 plots for grubbing were randomly selected. Plot locations were chosen by constructing a grid on a map of the island and then selecting locations based on randomly generated pairs of numbers. Only locations that fell in suitable habitat were selected and a few extra locations were selected beyond the number needed in case that location was not suitable for grubbing (too steep or to close to breeding Common Murres). Once a plot location was reached by the field crew, a stake was placed in one corner, and a 5 x 5 m grid was laid out with rope (20 m long) and three more stakes.

Each hole in all plots was assessed for puffin occupancy, with holes on the edge of the plot alternately included and excluded. Holes were classified into the following five categories; *unknown* (in which the end of the burrow could not be reached), *entrance* to another burrow, a *short* burrow (< 30 cm) that was not of sufficient length to accommodate a breeding puffin, an *empty* burrow, or an *occupied* burrow. *Occupied* burrows were those that contained an egg, a chick, an adult, an adult with its chick or egg, or other evidence of occupancy such as extensive nest material, chick faeces or egg shells from the current season. Useable burrows were defined as *occupied* burrows plus *empty* burrows. The slope of each plot was measured with a clinometer. A total of 40 plots were grubbed between 24 and 26 June 2003.

The area of each of the four sections was measured four times with a planimeter, to obtain a mean and a variance. This area was multiplied by the scale to obtain horizontal occupied area. The four horizontal areas were corrected for the slope of the habitat, using the mean and variance of the slopes measured in each plot. Finally, the slope corrected occupied area was multiplied by the occupied burrow density to estimate the total population size of puffins breeding on Gull Island (in pairs). The Delta method (Williams et al. 2002: 736-737) was used to combine the variances from each of the estimates. The error on the occupied area was based on the number of replicates taken with the planimeter (n = 4), while occupied burrow density and total population size were based on the number of plots sampled (n = 8 to 12) in each section.

Although not needed for calculating total population size, the following useful statistics were also calculated for comparisons with other studies. Burrow occupancy rates were calculated as the number of *occupied* burrows divided by the number of *occupied* burrows plus the number of *empty* burrows. Hole occupancy rates were calculated as the number of *occupied* burrows divided by the sum of the number of *occupied* burrows, the number of *empty* burrows, the number of *additional entrances* and the number of burrows too *short* to support a breeding pair. To calculate section-wide and island-wide occupancy rates each plot was weighted by the number of holes grubbed in the plot, therefore plots with greater number of holes contributed more to the calculation of mean rates. Mean burrow densities were not calculated by weighting by number of burrows in the plot. Standard errors were based on the number of plots grubbed (not the number of holes) in a section.

3.4.2 1984 and 1985

Similar protocols were used in 1984 and 1985 except for the following. First, random plots were randomly selected across all areas of appropriate habitat (i.e. the island was not stratified). Second, larger 30 m^2 circular plots were used. Finally, no assessment of occupied areas or hole counts were undertaken, so the occupied area calculated for 1979 by Cairns and Verspoor (1980) was used to estimate total population size. The grubbing took place from 31 July – 5 August 1984 and 10 – 16 July 1985 on Gull Island, and 4 – 28 August 1984 and 1 – 5 August 1985 on Great Island.

3.5 Black-legged Kittiwakes

Population estimates were based on a count of active nests (or apparently occupied nest; AON), which were assumed to represent a breeding pair. Active nests were those nests that appear completely constructed and well maintained, and although they were often attended by one or two adults, this was not a requirement to be considered active. Adult birds standing on ill-constructed or degraded nests were not counted as active nests. In areas where visibility was impeded by physical geography, especially gulches on the southern end of Gull Island and horizontal platforms and opposite facing slopes on Great Island, nests were counted from land and added to the count. Generally, the land counts occurred within the same week as the boat surveys.

3.6 Northern Fulmars

Northern Fulmars present on breeding ledges were recorded during the boat surveys. During some Razorbill ground surveys, adult fulmars present on ledges and eggs/chicks found were recorded, but the focus of the Razorbill surveys was not on counting fulmars, so birds and eggs/chicks were certainly missed. Records were also kept of incidental observations of nesting fulmars by researchers on both islands, and include counts of eggs and chicks, and counts of adult birds on nesting ledges. However, the extent of the information varied considerably between island and across years. As the sources and quality of the data varied annually, different data sets were used to produce annual counts.

3.7 Other species

Other breeding species were noted during routine field operations on the two islands. No systematic surveys were conducted for these species.

4. Results

4.1 Common Murres

4.1.1 Population estimates for study period

Between 1 636 and 2 814 Common Murres were counted on Gull Island, 2001-2003 (Table 1). Great Island had larger numbers with two counts at 9 996 and 12 706 in 2002 and 2003, respectively. K-ratios obtained at the Cairns plot on Great Island were similar among the two years they were assessed and were generally low (0.58 – 0.61; Table 1). Using these k-ratios, breeding population estimates of 998 to 1 632 pairs on Gull Island and 6 098 and 7 369 pairs on Great Island were calculated (Table 1).

Common Murres breed over most of Gull Island, but the bulk of breeding population is concentrated on the southern end of the island (Figure 2 and 3). A similar pattern was seen on Great Island (Figure 4).

4.1.2 Comparisons with previous surveys

Common Murre populations grew with a population growth rate (λ) of 1.068 ± 0.020 on Gull Island from 1942 to 2003, and 1.035 ± 0.006 on Great Island from 1972 to 2003 (Table 2). On Gull Island between 1971 and 2002, Common Murres have both increased at sites where they were present in 1971 and have expanded to occupy other areas (Figure 2 and 3). The core of the colony was on the east side of the island in 1971. Now major breeding concentrations are present on the west side of the Finger, and a major colony has developed on the southeast corner of the island. Colonies have also developed on the west and north side of the island.

4.2 Razorbills

4.2.1 Population estimates for study period

On Gull Island, 172 - 285 Razorbills were counted from ground counts in 1999-2003 (Table 3). Boat counts were consistently lower with 94 - 195 counted between 2001 and 2003, and averaged 41.7% lower than the ground counts (Table 3). Similarly on Great Island, although only one year of data is available, the boat count (138 adults) on Great Island in 2003 was 37.5% lower than the ground count (221 adults) in 2003 (Table 3). Razorbills are scarce on the west side of Gull Island, being most commonly seen on the east side (Figures 5-7). They are more evenly distributed around Great Island (Figure 8).

The nesting area on the northwest and southwest corner of the Saddle on Gull Island had 13 eggs in 1999 and 15 eggs in 2003. Numbers of adults counted on these nesting areas were 11 in 1999 and 24 in 2003. Together, these combine for a k-ratio of 0.8. However, we chose not to use this correction factor at this time, as it only represents only one plot in just 2 years. Instead, we used a k-ratio of 1.0: k-ratios of about 1 were calculated for the Sainte-Marie Islands, a colony where adults are also counted rafting on the water (Chapdelaine et al. 2001), so is likely reasonable

4.2.2 Comparisons with previous surveys

Razorbill populations grew with a population growth rate (λ) of 1.052 ± 0.007 on Gull Island from 1943 to 2003, and 1.027 ± 0.007 on Great Island from 1972 to 2003 (Table 4). Between 1971 and 2002, Razorbills have both increased at sites where they were present in 1971 and have expanded to occupy other areas (Figures 5-7).

4.3 Atlantic Puffins

4.3.1 Population estimates for study period (1984-2003)

In 2003, Atlantic Puffins showed considerable variation in occupancy rates and densities of burrows across the four areas of Gull Island (Table 5). Occupied burrow rates were higher on the east side of the island, while they were lowest on the west side (Table 5). Burrow densities and occupied burrow densities were highest on the north

side, while lowest on the south side (Table 5). However, the north side only harboured 25 072 ± 2 629 breeding pairs, as total area was relatively small (Figure 9). The bulk of the breeding population occurred on the east and west sides of the island. In total an estimated 140 429 ± 5 088 (95% CL: 130 137 – 150 721) pairs of Atlantic Puffins bred on Gull Island in 2003 (Table 5).

Population size estimates for Gull Island calculated from the data collected in 1984 and 1985 were similar (Table 6). Occupied burrow rates tended to be quite high (0.782 and 0.874 in 1984-85) but burrow densities were much lower than 2003 (0.349 burrows/m^2 and 0.310 burrows/m^2 1984-85 versus a mean of 1.023 burrows /m^2 in 2003). An estimated 31 454 ± 2 799 (25 895 – 37 013) and 30 832 ± 2 417 (26 044 – 35 620) Atlantic Puffin pairs bred on Gull Island in 1984 and 1985, respectively. On Great Island, the estimates were quite high, due to high burrow densities and high occupancy rates (Table 7). An estimated 86 692 ± 7 955 (70 614 – 102 770) and 82 076 ± 6 461 (69 062 – 95 090) Atlantic Puffin pairs bred on Great Island in 1984 and 1985, respectively.

4.3.2 Comparisons with previous surveys

There are fewer estimates of Atlantic Puffin population sizes than for other species and the quality of these estimates varies (Table 7). Due to these uncertainties, interpretations of these older population estimates and trends are presented in the discussion.

4.4 Black-legged Kittiwakes

4.4.1 Population estimates for study period

Kittiwakes nest on most cliff ledges around Gull and Great Islands (Figure 10 and 11). We counted between 4 070 and 5 204 kittiwake nests on Gull Island in 2001-2003, and 9 292 and 10 237 nests on Great Island in 2002-2003 (Table 8).

4.4.2 Comparisons with previous surveys

Black-legged Kittiwake populations on Gull Island were increasing through the late 1960s-early1970s, but have substantially declined by the early 2000s (Table 8). With the long 30-year gap in the time-series, calculating a population growth rate was considered inappropriate. On Great Island, the population size was similar in 1968 and 1994 but had substantially declined by 2003, showing a 60.9% reduction between 1994 and 2003.

4.5 Northern Fulmars

4.5.1 Population estimates for study period

4.5.1 1 Gull Island

During the 1999 Razorbill survey, one fulmar egg was seen on the west side of the Finger, and 6 adults were seen on the east side of Gull Island (Figure 12). In 2000, 2 adult fulmars were noted on the west side of the Finger from incidental observations of field crews. In 2001, 1 fulmar was seen on a ledge on the west side of the Finger during the boat count. In 2002, fulmars were not noted during the boat count, however, 1 chick was found on the west side of the Finger and 3 eggs were found on the east side of the

Finger. In 2003, 6 fulmars were seen on ledges during the boat survey, 5 on the west side of the Finger and 1 on the east side of the Finger. Fulmars were not noted in the 2000, 2001 or 2003 Razorbill ground count.

4.5.1.2 Great Island

During the 2002 boat count, 19 fulmars were counted on the ledges facing the cabin (Figure 12). In 2003, 14 fulmars were seen on ledges during the boat count, 9 on the cliff facing the cabin, and 5 on the northwest corner of the island. During the Razorbill ground count, which only examined the southern two-thirds of the island, 29 fulmars were seen, 4 west of the cabin, 17 on the ledge facing the cabin, 6 in the southern most coves, and 2 on the main east-facing cliff of Great Island.

The cliff face across from the cabin has been surveyed for Northern Fulmars in more detail in recent years. In 2000, 27 site-holding adults were counted, 34 in 2001 and 20 in 2002. Of these, chicks were confirmed in 2 sites in 1999 (adults not counted in 1999), and 1 each in 2001 and 2002.

4.5.1.3 Population estimates

It was clear from our surveys that all fulmars could not be counted by any one technique, especially on Great Island. Some adults could only be seen from ground locations, others only from a boat. We present the maximum counts from our techniques as the annual population estimate (Table 9), and note that these most likely underestimate the total number of fulmars present. In the case of 2003, we combined the ground and boat count, to provide the most comprehensive estimate for Great Island between 1999 and 2003.

4.5.2 Comparisons with previous surveys

Although population counts for fulmars represent a mix of counts of sites-holding adults and eggs/chicks, there does not appear to be any great change in the population in the last 10-20 years (Table 9).

4.6 Current estimates

A summary of the most recent breeding population size estimates for seabirds breeding on Gull Island and Great Island are presented in Table 10.

5. Discussion

5.1 Common Murres

Our technique to count Common Murres was based on a single boat count, with the inclusion of some areas counted from the ground. For sub-colonies with relatively few birds (< 200) our technique should suffice to provide a reasonable estimate of the breeding population, as each individual murre is counted. In the case of larger sub-colonies, significant biases in the counts are possible as counts are based on counting sets of birds in 10s to 100s. In general, observers tend to bias counts of large numbers of birds low (Erwin 1982), so our estimate is more likely to underestimate the total breeding population. Additionally, birds hidden behind ledges or boulders would not have been counted, further lowering our estimate. Our k-ratio was based on a single small plot, which may result in a potential bias, although we feel it is a relatively

representative plot, as it occurs in an area long-used (minimum of 20 years) by breeding Common Murres, and the topography is similar to many of the flatter areas used by murres. The low k-ratio obtained from the plot is consistent that includes a growing population with many young prospecting birds (Gaston and Nettleship 1982, Hatch and Hatch 1989). If populations continue to grow, more intense methods, such as photographing denser areas and more plots for k-ratio monitoring may be warranted.

Since establishing breeding in the mid part of the 20th century, populations of Common Murres are continuing to increase on Gull and Great Islands. Great Island now harbours a significant breeding population, with over 7 000 pairs estimated to breed in 2003. Gull Island, previously only a relatively insignificant breeding colony, now has well over 1 000 breeding pairs. Areas occupied by murres have also increased, with more colonies present on Gull Island.

Population trends of Common Murres in Newfoundland and Labrador have been variable over the last 2-3 decades. The large population on Funk Island has apparently remained stable between 1972 and 2002, with an estimated 412 000 breeding pairs (Chardine et al. 2003). In Labrador, the population on the Gannet Islands declined between 1983 and 1998 from 60 000 pairs to 36 000 pairs (Robertson and Elliot 2002a), while the small populations in Groswater Bay increased, both in size and in the number of colonies (Robertson et al. 2002b). Populations of Common Murres on the Québec North Shore increased up to 1993 and stabilized by 1998-1999 (Rail and Chapdelaine 2002).

The reason that the Witless Bay population has continued to grow may be due to a number of factors. Significant numbers of Common Murres were captured in gill nets as fishery bycatch (Piatt and Nettleship 1987) until 1992 when the moratorium on groundfish fisheries was implemented. The removal of gill nets from the water around Witless Bay may have released the population from this mortality source and has allowed it to expand. Populations in Groswater Bay may also be benefiting from a reduction in fishing effort (Robertson et al. 2002b), as Groswater Bay used to be a major fishing grounds on the Labrador coast. Why Funk Island and Gannet Islands have not increased are not known, but may be due to intraspecific competition at the large Funk Island colony (Chardine et al. 2003), and disturbance by Arctic Foxes (*Alopex lagopus*) at the Gannet Islands (Robertson and Elliot 2002a).

5.2 Razorbills

Even though the Razorbill is a notoriously difficult species to monitor, our technique to monitor them in Witless Bay is still relatively crude. Both islands have a variety of habitat types, which include both accessible and inaccessible cliffs, boulder screes and rocky crevices. We suspect that our annual count of adults from the ground likely represents a minimum number of the breeding population, although our assumption that a bird equals one breeding pair has not been rigorously tested. The boat counts consistently produced numbers lower than the ground counts, which is not unexpected, as Razorbills nest in areas not readily observable from the boat. Furthermore, Razorbills nesting at higher sites probably do not flush from their nests while a boat passes by below.

For the purpose of monitoring this small population, we feel our technique of ground counting adults in nesting areas, although not ideal, is certainly adequate to

detect large scale trends. If possible, future work to include egg count plots to determine k-ratios would be worthwhile. The one plot on the Finger appears to be a good site, but other plots would be needed. Possible sites include sites on the east side of the Finger, and some nesting areas on the southeast portion of the island. However, given that most nesting areas are inaccessible, better estimates are likely not possible without much more intensive efforts.

Formerly, Razorbills were a very rare breeding species on Gull and Great Islands. Now, with populations numbering somewhere over 200 pairs on both islands, Razorbills, although by no means common, have increased to a level where they could be considered established and secure breeders in Witless Bay. Razorbill populations have been increasing at every North America colony examined in the last 10 years (Chapdelaine et al. 2001); clearly Witless Bay is no exception. Reductions in fisheries bycatch, hunting mortality, disturbance, competition with fisheries for forage fishes, have all likely played a role in releasing Razorbills from these mortality sources and allowing populations to grow.

5.3 Atlantic Puffins

Monitoring burrow-nesting species does not involve counting nests or birds directly, but rather involves assessing occupancy rates of burrows or holes and assessing the extent of area where burrows are present. As a result, Atlantic Puffins are difficult to monitor. For most of the older estimates, one or both of these components was not assessed in a rigorous manner, or the techniques used were not documented. However, regardless of the quality of the historical data for Atlantic Puffins the results from this study strongly suggest the population has substantially increased.

The 1979 estimate of 29 726 breeding pairs on Gull Island was well documented. Slope-corrected area occupied and burrow densities were calculated for 3 different areas (southwest cove, east slope and the rest of the island). Burrow occupancy rates from Great Island were used, as burrows were not grubbed on Gull Island. Since burrow occupancy rates were assessed late (29 Jul – 10 Aug) in 1979, Rodway et al. (1996) felt the estimates for both Great and Gull Islands were potentially biased low. However, previously unpublished data from 1984 and 1985 from Gull Island gave population estimates of about 31 000 pairs, close to the 29 726 in 1979, suggesting the 1979 estimate may not have been that badly biased.

The over four-fold increase in numbers of breeding puffins on Gull Island between 1979 and 2003 were driven both by an increase in occupied burrow densities and total occupied areas. In 1979, 113 796 m^2 of area was occupied; this value had doubled by 2003 to 246 660 m^2. Burrow densities in 1979 averaged 0.55 burrows/m^2, ranging from 0.14 – 0.86 across 3 areas (Cairns and Verspoor 1980). In 2003, the average almost doubled to 1.023 burrows/m^2. Burrow occupancy rates only increased slightly, from a 0.441 in 1979 to 0.578 in 2003. Therefore, the increase was roughly equally driven by two factors, a doubling of the total area occupied by puffins, and a near doubling of the burrow densities within the occupied areas. Increases in the occupancy rates of burrows were only a minor factor explaining the increase.

Previous to this study, there were indications that the breeding population of puffins on Gull Island had been increasing. Calvert and Robertson (2002a) used a variety of population size estimators based on marked puffins to assess the relative

numbers of juveniles and adults, and non-breeders and breeders using a study plot. Combined with literature values for adult survival rates, Calvert and Robertson (2002a) estimated that populations on Gull Island were likely increasing (values for λ ranging from 0.97 – 1.19), and that fecundity was very high, so high that they suspected that immigrants from other colonies may be recruiting to Gull Island. Breeding propensity values were estimated to be quite low, suggesting that density-dependent habitat limitation may be occurring on Gull Island.

Trends on Great Island are more difficult to interpret, as the 1979 estimate of 52 000 may have been biased low due to the late-timing of examining burrows which resulted in low burrow occupancy rates (Rodway et al. 1996, 2003). The data from 1985 and especially 1984 were collected late as well, but both surveys indicated high occupancy rates (0.84-0.90) and resulted in higher population estimates of 82 000 – 87 000. Occupied area did increase modestly (18%) between the 1979 and 1994 survey as well, further suggesting that the population had increased (Rodway et al. 1996, 2003).

Atlantic Puffin population trends have been quite variable in eastern North America. The second largest colony in eastern North America, the Gannet Islands, showed a mix of trends among the 6 islands, with an overall slight decline in the breeding population between 1978 and 1999 (Robertson and Elliot 2002a). Similarly, in Groswater Bay, populations declined on 2 islands, increased on 1 and remained stable on 3 between 1978 and 2002 (Robertson et al. 2002b). Small Island, in northeast Newfoundland, showed a dramatic decline from 1984 to 2000, likely driven by predation risk due to Great Black-backed Gulls (Robertson and Elliot 2002b). In the Migratory Bird Sanctuaries on the North Shore of the Gulf of St. Lawrence, Atlantic Puffin populations have varied considerably since 1925, ranging from a low of 14 716 in 1977 to a high of 71 914 in 1935. Recently, the population increased between 1977 and 1993, only to decline again by 1998-1999 (Rail and Chapdelaine 2002). Overall, Atlantic Puffin population trends are quite variable, and vary considerably among colonies in eastern North America. Fortunately, the large colonies in Witless Bay have increased, fortifying numbers at the core of the breeding range. Whether the colonies in Witless Bay continue to increase remains to be seen, but given the evidence for possible density-dependent habitat limitation, and the degradation of habitat on the islands, increases may slow and the populations may stabilize in the future. Interestingly, burrow occupancy rates on Gull Island in 2003 were low (0.578) compared to the 1984-85 (0.774-0.849) rates and 0.879 obtained on Great Island in 1993, possibly providing early evidence that increases seen on Gull Island may be beginning to stabilize.

5.4 Black-legged Kittiwakes

Black-legged Kittiwake populations appeared to be increasing in the late 1960s and early 1970s, but in the interim, populations in Witless Bay dramatically declined by the early 2000s. Unfortunately, with the gaps in the time-series it is difficult to determine when these declines occurred. The only data point that sheds some light is the estimate for Great Island in 1994 provided by Rodway et al. (1996). Between 1968 and 1994, the population on Great remained essentially unchanged, suggesting that the decline occurred in the last decade. Studies on the biology of kittiwakes in Witless Bay showed that reproductive success of kittiwakes plummeted in 1992 and 1993 (Regehr and Montevecchi 1997), when delays in the arrival of capelin inshore were noted. With the exception of 1996, reduced breeding success has been noted on Gull Island since 1990 (Chardine, pers. comm.). Further studies in the late 1990s and early 2000s have showed

that predation by gulls on kittiwakes is significantly reducing their breeding success (Massaro et al. 2000), and that Great Black-backed Gulls are killing significant numbers of adults (Veitch 2003). There are few comparable data series available on kittiwake populations at sizeable colonies in Newfoundland and Labrador. On the Québec North Shore, kittiwake populations increased steadily until 1988, after which they have also declined up to the last survey in 1998-1999 (Rail and Chapdelaine 2002).

Even though current trends in Witless Bay can only be assessed with 2 or 3 years of data, both islands are showing evidence that declines in populations are continuing. In fact, from 2001 to 2003, the kittiwake population on Gull Island declined by 17%. Therefore, the decline in kittiwake populations is probably continuing, and may even be accelerating in recent years. As kittiwakes can be relatively long-lived, reductions in the population size may only be seen after a number of years of failed breeding. Further, since it has been over 10 years since changes in fishing practices have reduced fisheries offal and the delayed arrival of capelin, gull populations may have adjusted to the new feeding conditions and further focused their foraging efforts on kittiwakes.

Given the steep and apparently continuing declines in Black-legged Kittiwake populations, efforts to monitor Witless Bay, and other colonies, should be undertaken and possibly augmented, especially given the relative ease of counting kittiwake nests.

5.5 Northern Fulmars

Our surveys only represent one boat or land count. Fulmars were generally not the focus of these counts, and we did not confirm breeding, so our counts are most likely low. Future work should combine more extensive ground searches with a boat survey more focused on fulmars. We believe our 2003 estimates are quite thorough, and probably represent only a slight underestimate of the current population size.

Breeding fulmars were first confirmed in Atlantic Canada in 1973 on Great Island (Nettleship and Montgomerie 1974). Stenhouse and Montevecchi (1999b) documented the increase in Northern Fulmar populations at colonies in Newfondland and Labrador in the 1970s to the 1990s. Numbers in Witless Bay appear to have stabilized, and there are no signs that the population is continuing to increase. Although the underlying reason for the cessation of the increase in fulmars is not known, a possible explanation is that with the reductions in fish offal since the moratorium in 1992, less food is available and fulmars are not as attracted to the general area for nesting.

5.6 Gulls and Leach's Storm-Petrels

Recent population sizes and trends for Herring Gulls and Great-Black-backed Gulls have been previously published (Robertson et al. 2001). In general, Herring Gull populations have decreased since the 1970s, while the small Great Black-backed Gull population has probably remained stable. The large Leach's Storm-Petrel populations have remained notably stable on both Gull Island (Robertson et al. 2002b) and Great Island (Stenhouse et al. 2000), in spite of evidence of rather significant numbers of storm-petrels being taken by gulls (Stenhouse et al. 2000, Veitch 2003).

5.7 Other species

A pair of Bald Eagles (*Haliaeetus leucocephalus*) continued to nest on Gull Island from 1999-2003. A nest has been active on the northwest corner of the island, back in the forested area, for many years. The nest was not checked regularly, but in years when it was investigated, chicks were generally present. Observers generally noted that murre carcasses were especially common under the nest site. Disturbances to nesting seabirds by eagles has been noted regularly by field crews.

A pair of Northern Ravens (*Corvus corax*) began nesting on the southeast corner of Gull Island (Gulch) in 2002, and was also present in 2003. In both years, chicks were hatched, although the number of fledglings was not noted. On Great Island, a pair of ravens has nested on the southeast corner of the island since 2000. These observations represent the first nesting record of this species in the Witless Bay Islands Ecological Reserve. Ravens can be significant predators of seabird eggs and chicks (Gaston and Elliot 1996), so it will be worth monitoring future nesting of this species in the Reserve.

Black Guillemots (*Cepphus grylle*) remain a rare nesting seabird in the Reserve. Populations were not monitored during the period of this report, but likely no more than 10 pairs breed on Gull Island and probably fewer on Great Island. As systematic surveys were not conducted for these species, numerical estimates are not available.

A brood of 3 Green-winged Teal (*Anas crecca*) and an accompanying hen were found in a pond on the Finger in 2001, in the middle of one of the densest Herring Gulls areas on the island. The young were still flightless, so the clutch must have been laid on Gull Island. Waterfowl have not been noted nesting in the Reserve since then.

6. Summary

In spite of large-scale changes in the oceanography and fisheries that occurred through the 1990s, seabird populations on Gull and Great Islands are faring well by the early 2000s. The notable exception is Black-legged Kittiwake. Since kittiwake populations are declining throughout their range in the Atlantic, likely little can be done for kittiwakes nesting in Witless Bay besides continuing to monitor their numbers. Populations of all auk species are showing signs of increasing. Notably, the large and important Atlantic Puffin population in Witless Bay appears to be healthy. The increase in puffin numbers is leading to habitat degradation across the islands, and eventually puffin numbers in Witless Bay may decline as appropriate habitat becomes degraded and limited. Witless Bay continues to remain a major breeding area for Leach's Storm-Petrel. Northern Fulmars appear to have stopped increasing in the Reserve and numbers have somewhat stabilized.

In light of potential and possible future threats to seabird populations, it becomes increasingly important to understand how factors influence population demographics. Population dynamics can be influenced by changing forage fish distribution, a changing local fishery, by-catch, climate change, mortality from chronic oil pollution, hunting, changing predator distribution and colony disturbance (Montevecchi and Tuck 1987, Chapdelaine et al. 2001, Montevecchi 2002). Continuing the monitoring of seabird colonies will help to understand which factors are most important in influencing seabird populations. Future work should focus on Green Island, as the size of the second largest

Common Murre colony in the Northwest Atlantic remains unknown. The large Atlantic Puffin population should also be surveyed on Great Island as soon as possible.

7. Acknowledgments

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Table 1. Boat counts (individuals), k-ratios and breeding population size estimates (pairs) of Common Murres on Gull and Great Island, Witless Bay, 2001-2003.

	Boat count		Cairns plot[1]		Population estimate	
Year	Gull Island	Great Island	Eggs / adults	k-ratio	Gull Island	Great Island
2001	2 004				1 172 ± 140[2]	
2002	1 636	9 996	30 / 49	0.61 ± 0.07	998 ± 115	6 098 ± 700
2003	2 814	12 706	29 / 50	0.58 ± 0.07	1 632 ± 197	7 369 ± 889

[1] data courtesy of Anne Storey

[2] based on mean of k-ratio from 2002 and 2003

Table 2. Estimates of the number of pairs of Common Murres breeding on Gull and Great Islands, Witless Bay, Newfoundland.

Year	Gull Island	Great Island	Source
1942	50		Peters and Burleigh (1951)
1962	4		Haycock (1973)
1969	136		Haycock (1973)
1970	260		Haycock (1973)
1971	316		Haycock (1973)
1972		1 970	M. Clements, unpubl. data
1973	680	2 800	Brown et al. (1975)
1977	589		Mahoney (1980)
1978	687		Mahoney (1980)
1979	680		Cairns and Verspoor (1980)
2001	1 172		this study
2002	998	6 098	this study
2003	1 632	7 369	this study

Table 3. Boat and ground counts of Razorbills on Gull and Great Island, 1999-2003. Dates of survey are below the count.

	Gull Island		Great Island	
Year	Ground count	Boat count	Ground count	Boat count
1999	172 (22 June)			
2000	261 (20 July)			
2001	213 (17-18 July)	94 (15 June)		
2002	228 (8 July)	142 (4 July)		185 (4 July)
2003	285 (15 July)	195 (2 July)	221 (11 July)	138 (2-3 July)

Table 4. Estimates of the number of Razorbill breeding pairs on Gull and Great Islands, Witless Bay, Newfoundland.

Year	Gull Island	Great Island	Source
1943	25		Peters and Burleigh (1951)
1959	10		L. M. Tuck, pers. comm. *in* Haycock (1973)
1969	39		Haycock (1973)
1970	47		Haycock (1973)
1971	37		Haycock (1973)
1972		70	M. Clements, unpubl. data
1973	30	120	Brown et al. (1975)
1979	50	100	Cairns and Verspoor (1980)
1983	60		Montevecchi and Tuck (1987)
1999	172		this study
2000	261		this study
2001	213		this study
2002	228	185	this study
2003	285	221	this study

Table 5. Occupancy rates, burrow densities and extent of occupied areas of Atlantic Puffins breeding on Gull Island in 2003. Horizontal occupied areas are areas measured directly from maps, while slope corrected areas were used to extrapolate total puffin breeding population size. Sample sizes to calculate standard errors and 95% confidence intervals for areas occupied are based on the four replicates of measurements taken with the planimeter. All others are based on the number of plots assessed.

	North	East	South	West	Total
Number of plots	10	12	8	10	40
Occupied hole rate	0.409 ± 0.030 (0.340 – 0.477)	0.424 ± 0.044 (0.326 – 0.522)	0.358 ± 0.044 (0.254 – 0.462)	0.351 ± 0.037 (0.267 – 0.434)	0.392 ± 0.020 (0.352 – 0.432)
Occupied burrow rate	0.592 ± 0.041 (0.499 – 0.684)	0.637 ± 0.054 (0.517 – 0.756)	0.570 ± 0.061 (0.425 – 0.715)	0.493 ± 0.045 (0.390 – 0.596)	0.578 ± 0.026 (0.526 – 0.630)
Burrow density (/m^2)	1.284 ± 0.064 (1.140 – 1.428)	1.030 ± 0.121 (0.764 – 1.296)	0.735 ± 0.208 (0.2422 – 1.228)	0.984 ± 0.088 (0.786 – 1.182)	1.023 ± 0.066 (0.890 – 1.156)
Occupied burrow density (/m^2)	0.760 ± 0.084 (0.572 – 0.947)	0.659 ± 0.088 (0.465 – 0.847)	0.419 ± 0.129 (0.122 – 0.717)	0.485 ± 0.046 (0.384 – 0.587)	0.591 ± 0.039 (0.513 – 0.669)
Horizontal occupied area (m^2)	31 422 ± 174 (30 868 - 31 976)	75 684 ± 45 (75 541 – 75 827)	39 043 ± 85 (38 771 – 39 313)	75 178 ± 20 (71 514 – 71 642)	217 727 ± 100 (217 514 – 217 940)
Angle of plots (°)	17.8 ± 3.2 (10.7 – 24.9)	27.3 ± 2.4 (22.1 – 32.6)	25.4 ± 3.7 (16.7 – 34.1)	32.9 ± 1.4 (29.7 – 36.1)	26.0 ± 1.6 (22.8 – 29.1)
Slope corrected occupied area[1] (m^2)	33 002 ± 194 (32 385 - 33 619)	85 194 ± 116 (84 825 – 85 563)	43 213 ± 131 (42 797 – 43 630)	85 215 ± 66 (85 040 – 85 461)	246 660 ± 135 (246 373 – 246 947)
Total population size (pairs)	25 072 ± 2 629 (19 123 – 31 020)	55 870 ± 7 149 (39 698 – 71 605)	18 115 ± 5 219 (6 308 – 30 457)	41 372 ± 3 667 (33 055 – 49 690)	140 429 ± 5 088 (130 137 – 150 721)

[1]Calculated by

$$a_{corrected} = \frac{a_h}{\cos(\theta)}$$

Where θ is the mean angle of the slope and a_h is the horizontal measure of the occupied area.

Table 6. Occupancy rates, burrow densities and assumed extent of occupied areas of Atlantic Puffins breeding on Gull Island and Great Island, in 1984 and 1985. Sample sizes to calculate standard errors and 95% confidence intervals are based on the number of plots assessed.

	Gull Island		Great Island	
	1984	1985	1984	1985
Number of plots	100[1]	128[1]	40	45
Occupied hole rate	0.541 ± 0.018 (0.504 – 0.578)	0.557 ± 0.015 (0.526 – 0.587)	0.573 ± 0.027 (0.518 – 0.627)	0.617 ± 0.024 (0.568 – 0.665)
Occupied burrow rate	0.792 ± 0.017 (0.759 – 0.825)	0.874 ± 0.011 (0.852 – 0.825)	0.843 ± 0.015 (0.812 – 0.875)	0.904 ± 0.011 (0.882 – 0.926)
Burrow density (/m^2)	0.349 ± 0.029 (0.291 – 0.408)	0.310 ± 0.023 (0.265 – 0.356)	0.764 ± 0.066 (0.660 – 0.928)	0.701 ± 0.055 (0.592 – 0.811)
Occupied burrow density (/m^2)	0.276 ± 0.025 (0.228 – 0.325)	0.271 ± 0.021 (0.229 – 0.313)	0.669 ± 0.061 (0.545 – 0.793)	0.634 ± 0.050 (0.533 – 0.734)
Occupied area (m^2)[a]	113 796	113 796	129 518	129 518
Total population size (pairs)	31 454 ± 2 799 (25 895 – 37 013)	30 832 ± 2 417 (26 044 – 35 620)	86 692 ± 7 955 (70 614 – 102 770)	82 076 ± 6 461 (69 062 – 95 090)

[1] Only 94 and 119 plots used in the calculations in Gull Island in 1984 and 1985, respectively, as 6 and 9 plots did not contain any burrows.
[a] from Cairns and Verspoor (1980), based on measurements made in 1979.

Table 7. Population size estimates (in pairs) for Atlantic Puffins breeding on Gull and Great Island, Witless Bay.

Year	Gull Island	Great Island	Source
1942	1 000		Peters and Burleigh (1951)
1950	5 000	5 000	L. M. Tuck pers comm. to D. N. Nettleship
1969	100 000		Haycock (1973)
1973	60 000	148 000	Brown et al. (1975)
1979	29 726 (71 000)[1]	51 653	Cairns and Vespoor (1980)
1984	31 454	86 692	this study
1985	30 832	82 076	this study
1994		123 000	Rodway et al. (1996, 2003)
2003	140 429		this study

[1] Revised estimate provided by Rodway et al. (1996, 2003).

Table 8. Estimates of the number of Black-legged Kittiwake breeding pairs on Gull and Great Islands, Witless Bay, Newfoundland.

Year	Gull Island	Great Island	Source
1942	500		Peters and Burleigh (1951)
1950	500	500	L. M. Tuck pers comm. to D. N. Nettleship
1951	500		L. M. Tuck, pers. comm. *in* Haycock (1973)
1968		23 229	Brown et al. 1975
1969	6 977		Haycock (1973)
1970	8 306		Haycock (1973)
1971	10 140		Haycock (1973)
1994		23 787	Rodway et al. (1996)
2001	5 204		this study
2002	4 070	10 237	this study
2003	4 314	9 292	this study

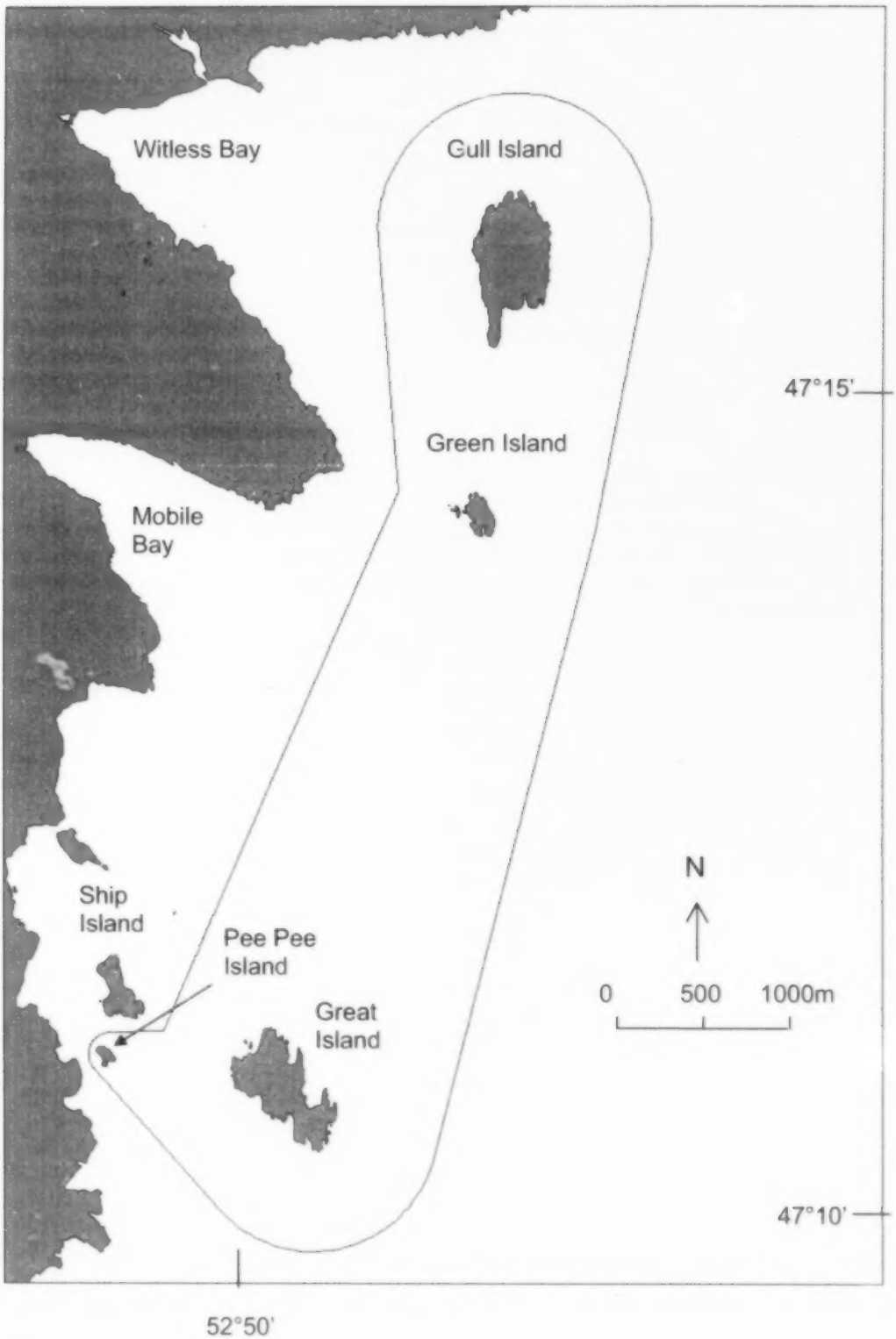
Table 9. Number of Northern Fulmar breeding pairs (egg/chick present at site) and number of site-holding pairs, possibly breeding or on empty site, in parentheses, on Gull and Great Island, Witless Bay.

Year	Gull Island	Great Island	Source
1973		6+(4)	Nettleship and Montgomerie (1974)
1974		(8-10)	Stenhouse and Montevecchi (1999b)
1975		(12)	Stenhouse and Montevecchi (1999b)
1979		17+(11)	Cairns and Verspoor (1980)
1983		(17)	Stenhouse and Montevecchi (1999b)
1989	(1)		Stenhouse and Montevecchi (1999b)
1993	(2)	(17)	Stenhouse and Montevecchi (1999b)
1994		(29)	Stenhouse and Montevecchi (1999b)
1996	3 + (1)	10+(36)	Stenhouse and Montevecchi (1999b)
1997	(4)	18+(30)	Stenhouse and Montevecchi (1999b)
1999	1 + (6)		this study
2000	(2)		this study
2001	(1)		this study
2002	4	(19)	this study
2003	(6)	(34)	this study

Table 10. Most recent population sizes estimates for breeding seabirds on Gull and Great Islands, Witless Bay Ecological Reserve.

	Gull Island		Great Island		
	Year	Population size (pairs)	Year	Population size (pairs)	Sources
Common Murre	2003	1 632	2003	7 369	this study
Razorbill	2003	285	2003	221	this study
Atlantic Puffin	2003	140 429	1994	123 000	this study, Rodway et al. (2003)
Black-legged Kittiwake	2003	4 314	2003	9 292	this study
Great Black-backed Gull	2000	88	2000	28	Robertson et al. (2001)
Herring Gull	2000	2 698	2000	1 640	Robertson et al. (2001)
Northern Fulmar	2003	6	2003	34	this study
Leach's Storm-Petrel	2001	351 866	1997	269 765	Robertson et al. (2002a), Stenhouse et al. (2000)

Figure 1. Map of the Witless Bay Islands Ecological Reserve, Newfoundland. Line surrounding the islands represents the current boundary protecting the Reserve from commercial marine traffic, as defined in the Witless Bay Islands Ecological Reserve Management Plan (1994).


Witless Bay
Gull Island
47°15'
Green Island
Mobile
Bay
Ship
Island
Pee Pee
Island
Great
Island
N
0
500
1000m
47°10'
52°50'

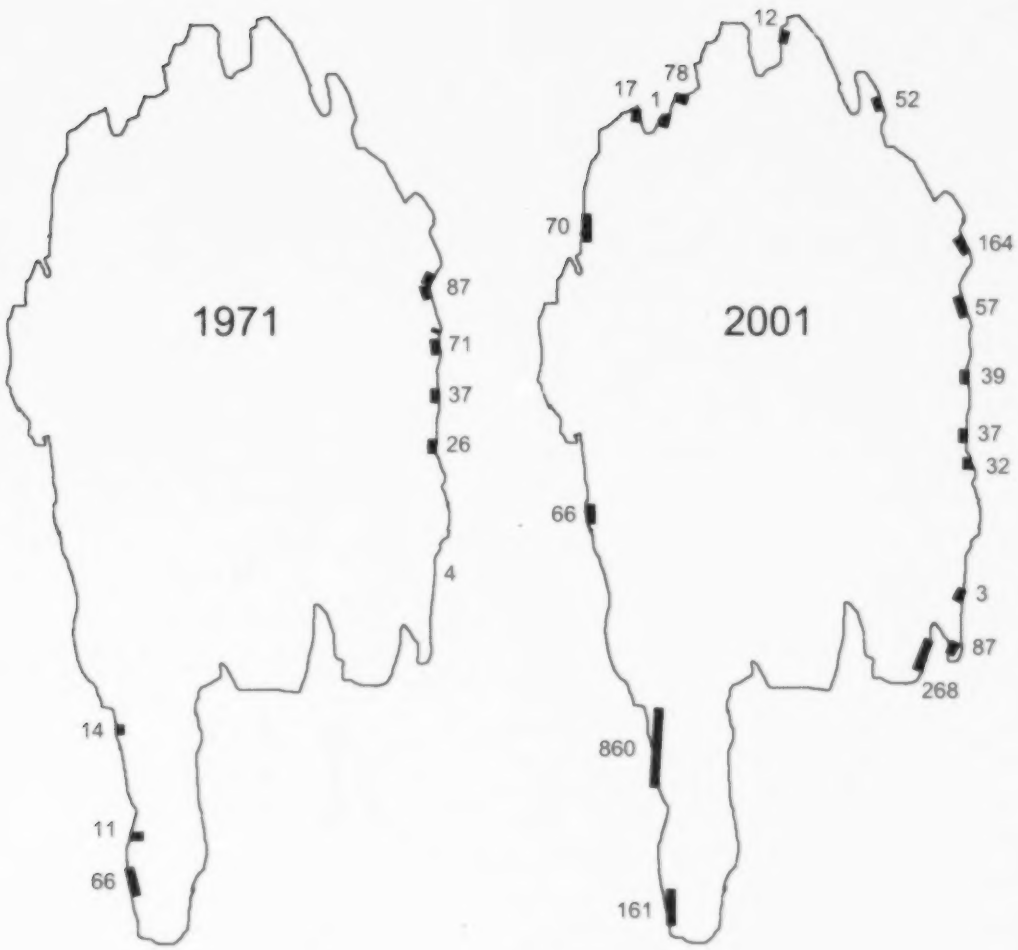


Figure 2. Distribution of Common Murres breeding on Gull Island, Witless Bay, 1971 and 2001, based on boat counts of individual adults.

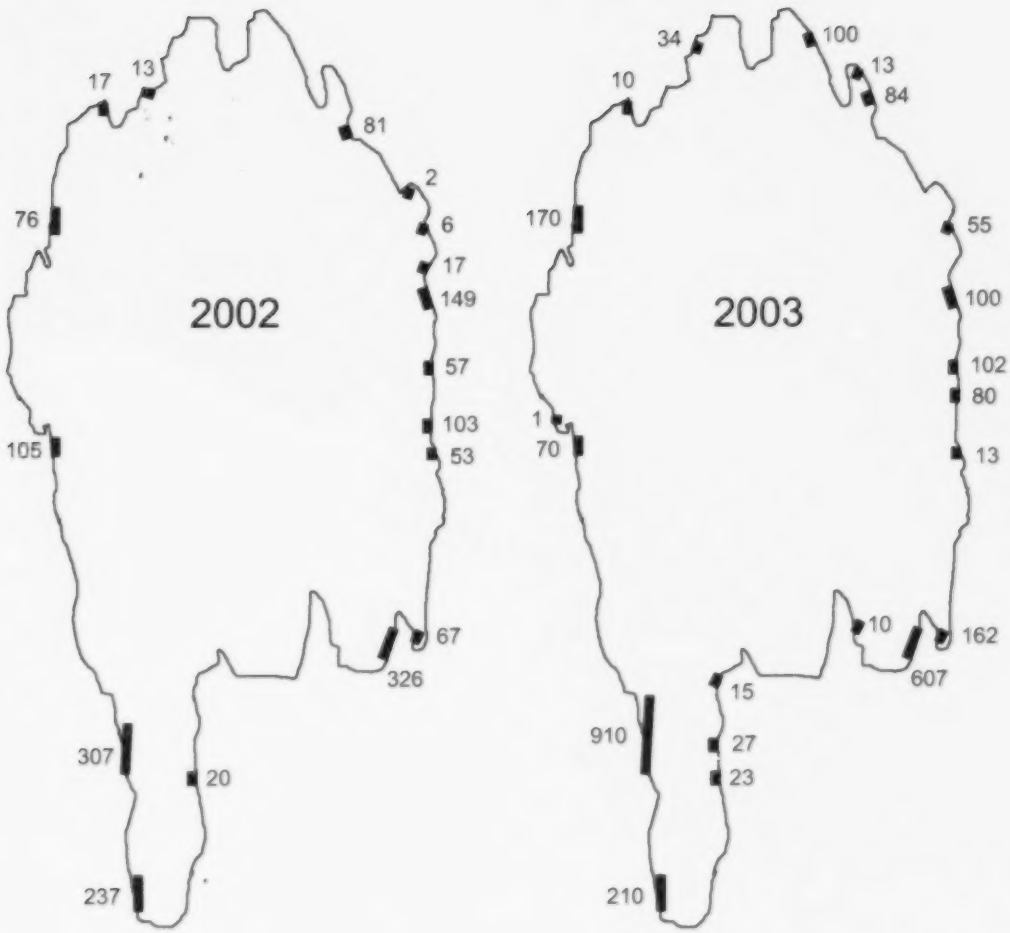


Figure 3. Distribution of Common Murres breeding on Gull Island, Witless Bay, 2002-2003, based on boat counts of individual adults.

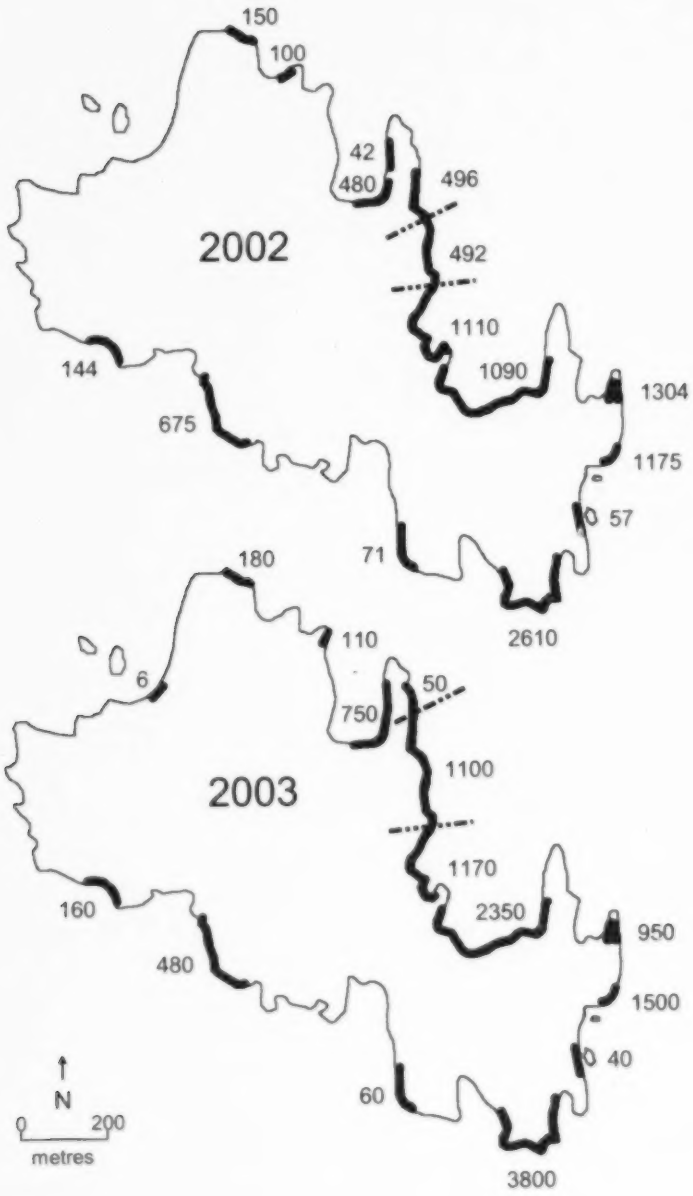


Figure 4. Distribution of Common Murres breeding on Great Island, Witless Bay, 2002-2003, based on boat counts of individual adults.

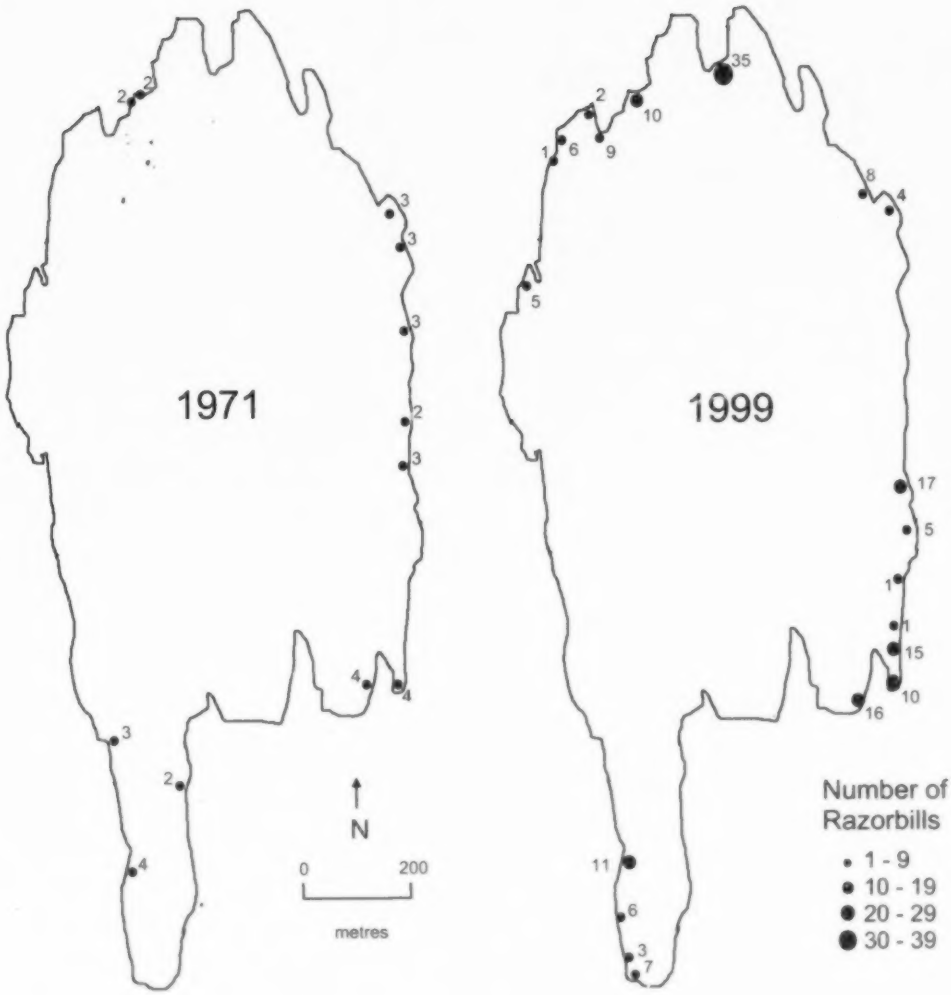


Figure 5. Distribution of Razorbills breeding on Gull Island, Witless Bay, 1971-1999, based on ground counts of individual adults.

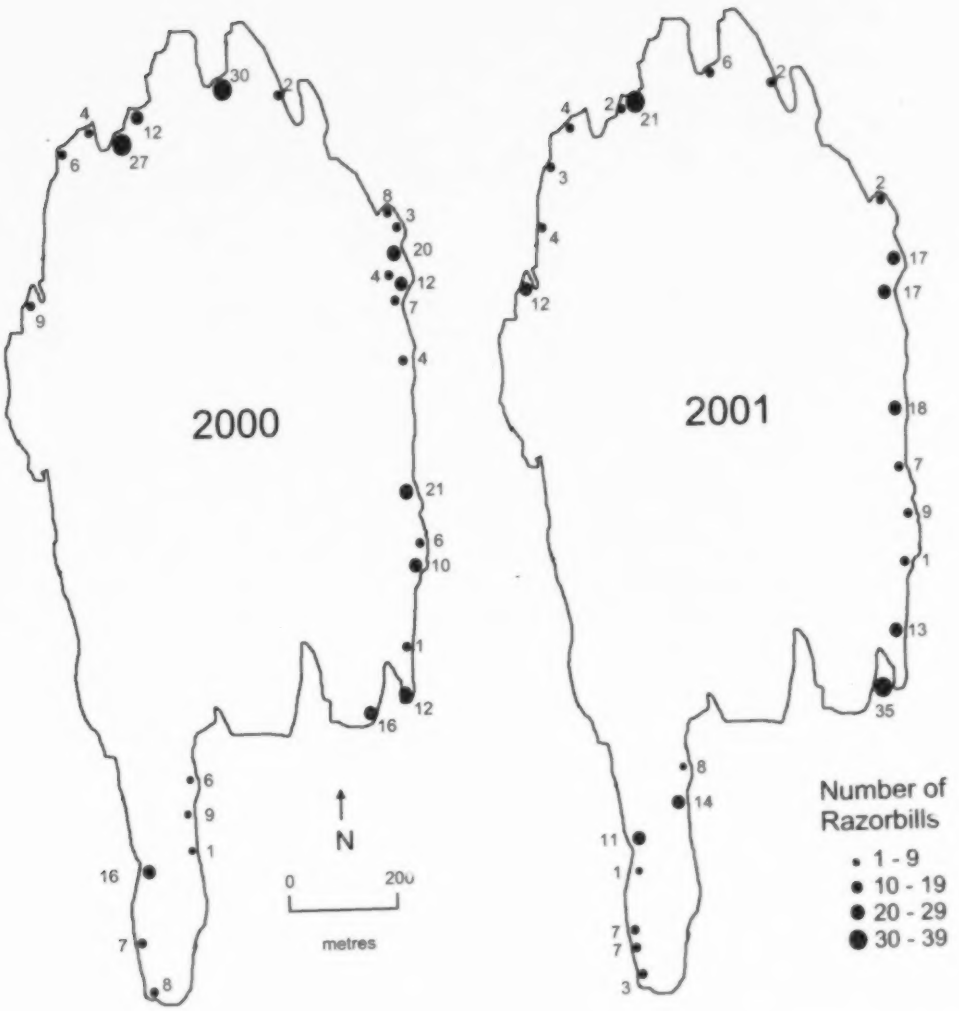


Figure 6. Distribution of Razorbills breeding on Gull Island, Witless Bay, 2000-2001, based on ground counts of individual adults.

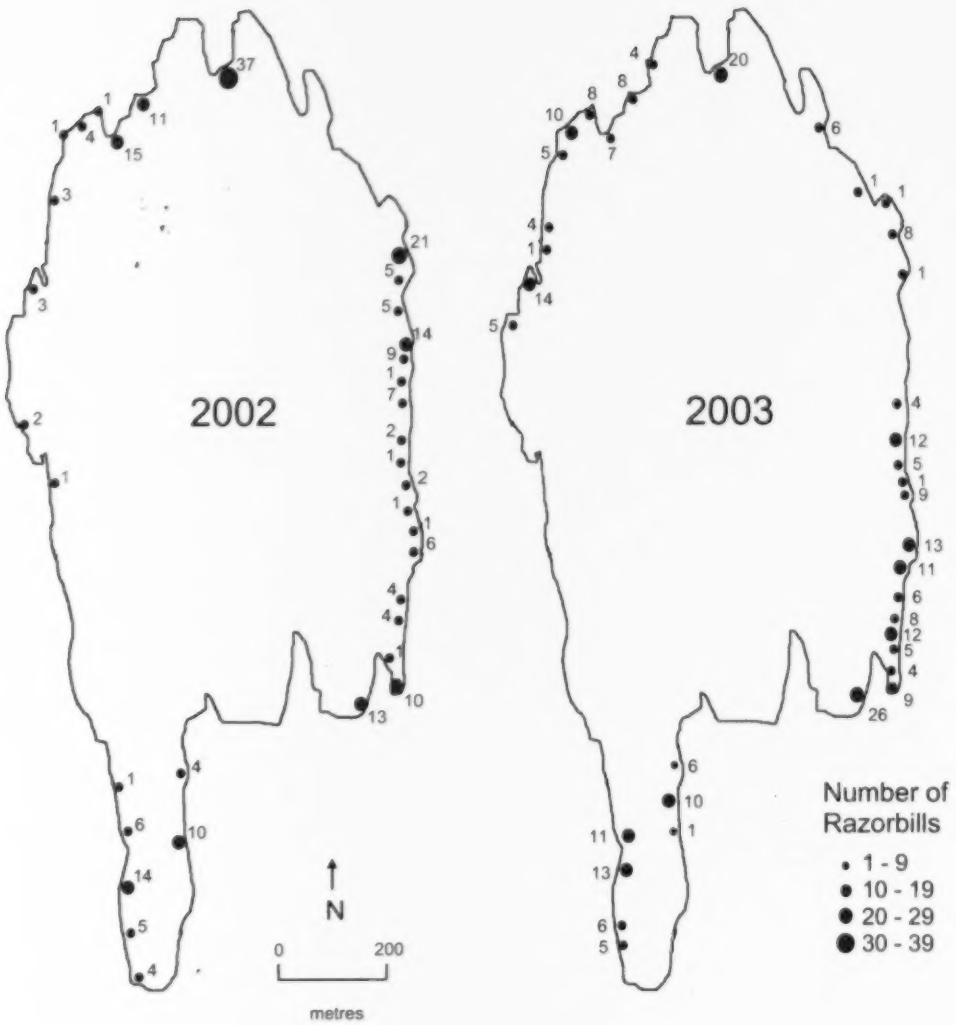


Figure 7. Distribution of Razorbills breeding on Gull Island, Witless Bay, 2002-2003, based on ground counts of individual adults.

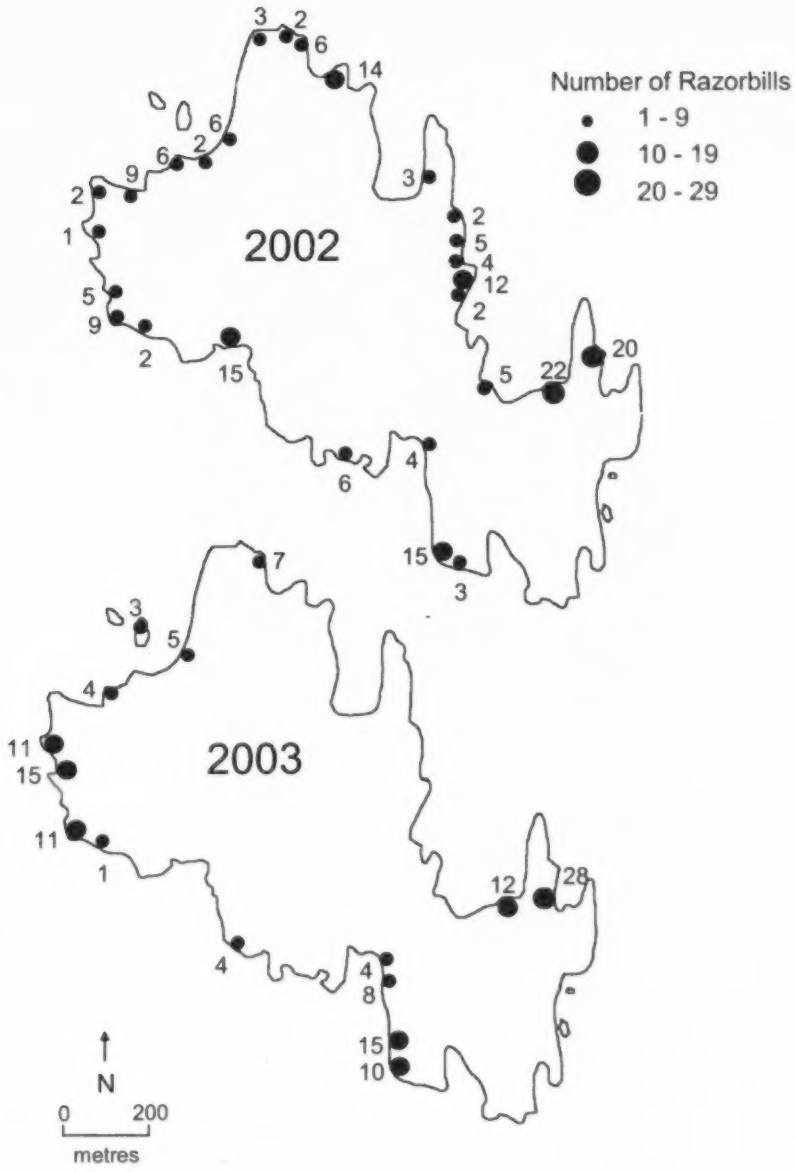


Figure 8. Distribution of Razorbills breeding on Great Island, Witless Bay, 2002-2003, based on boat counts of individual adults.

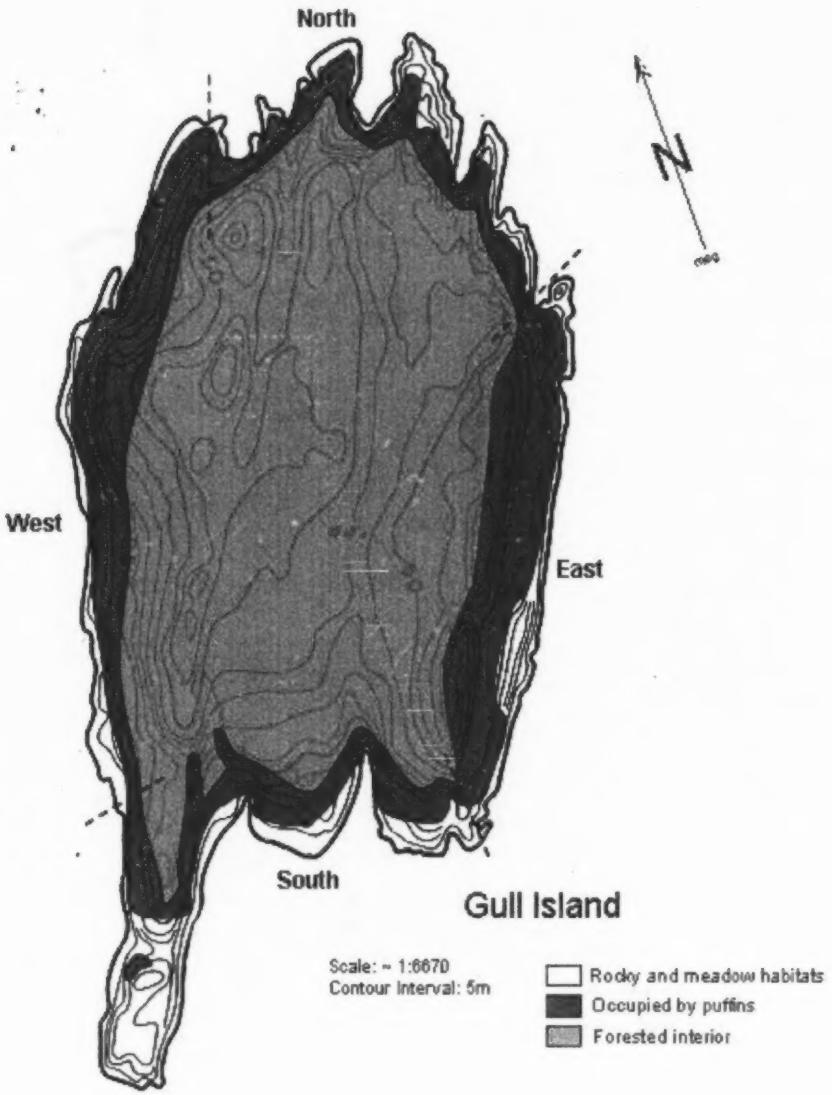


Figure 9. Extent of occupied breeding habitat by Atlantic Puffins on Gull Island 2003.

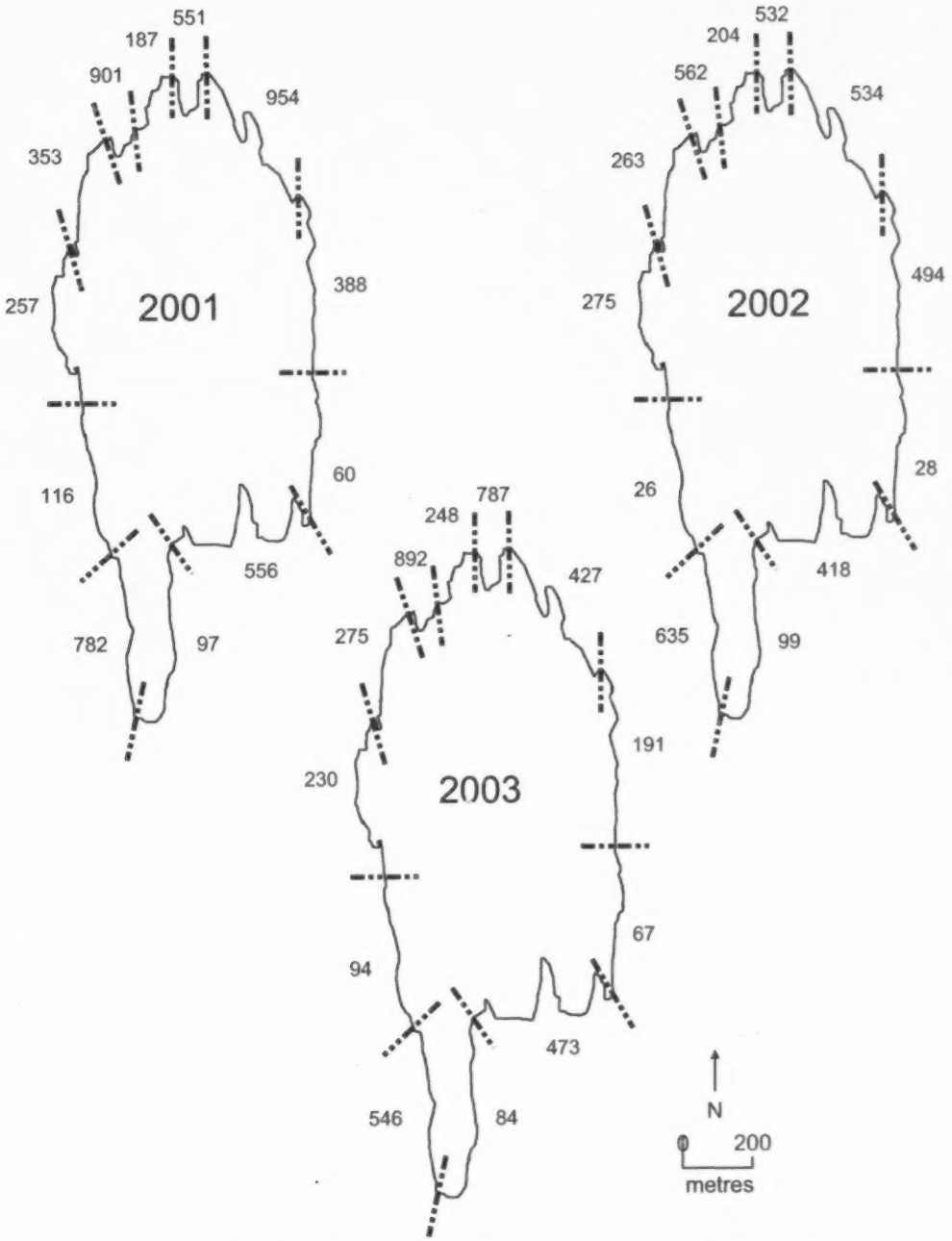


Figure 10. Distribution of Black-legged Kittiwakes breeding on Gull Island, Witless Bay, 2001-2003, based on boat counts of apparently occupied nests.

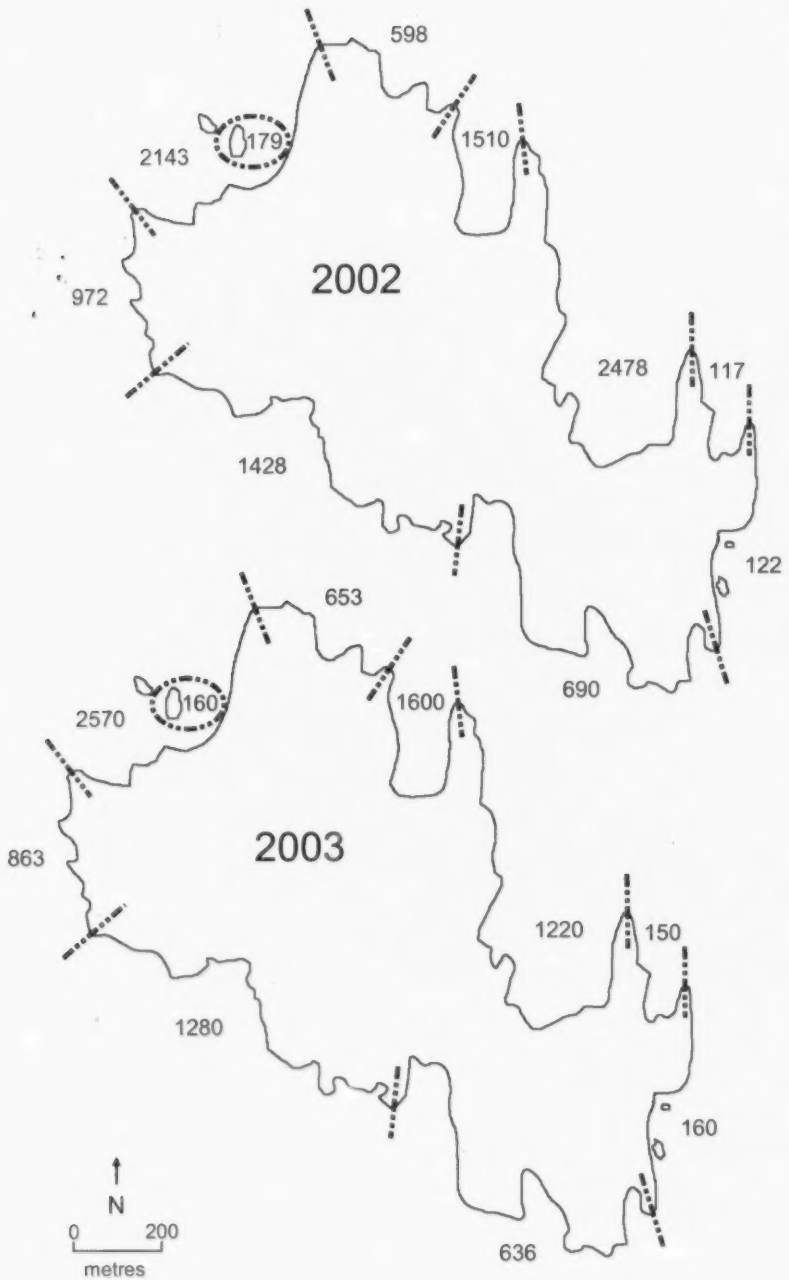


Figure 11. Distribution of Black-legged Kittiwakes breeding on Great Island, Witless Bay, 2002-2003, based on boat counts of apparently occupied nests.

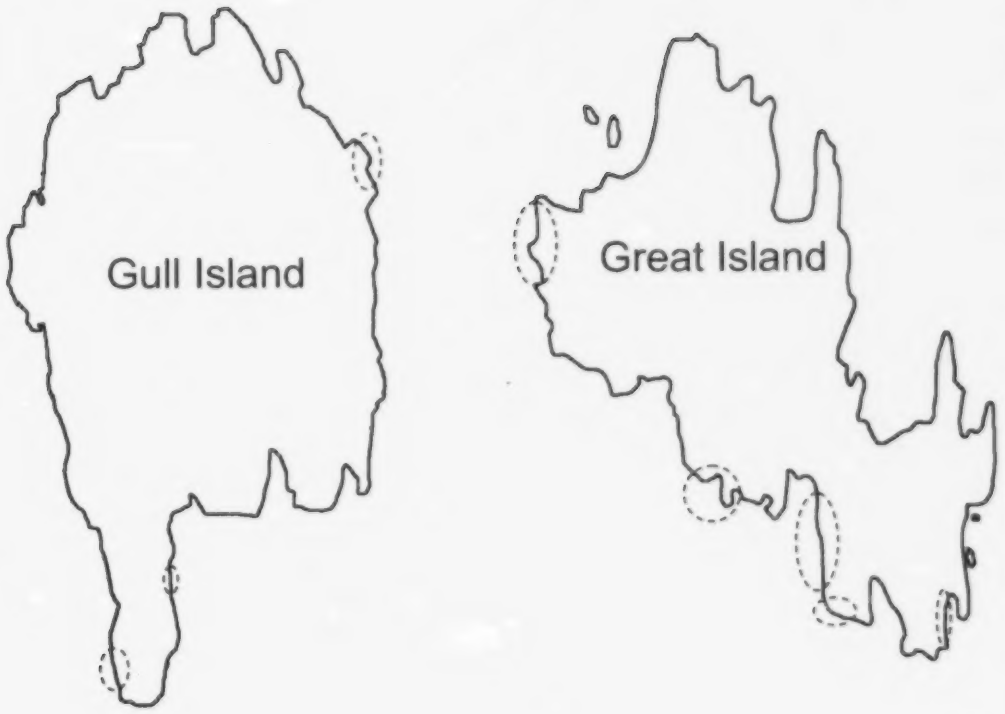


Figure 12. General nesting locations of Northern Fulmars on Gull and Great Island, 1999-2003.